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Theory of Automatic Control 3
Model Predictive Control

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1 Design of the MPC

The given controlled process is second order and its transfer function looks like:

$$G(s) = \frac{2.2500}{1.5625s^2 + 5.0625s + 1.0000} \tag{1}$$

To design model predictive controller MPC we need to transfer continuous time system to discrete time state space with sampling time T_s equal time constatnt T of system divided by four to obtain discrete time matrices A, B, C, D. On the equation below, we can see discrete state space model.

$$x(k+1) = Ax(k) + Bu(k) \tag{2a}$$

$$y(k) = Cx(k) \tag{2b}$$

where $x(k), u(k)$ and $y(k)$ represents states respectively inputs and outputs of system in specific time period. Initial conditions for states of our process x_0 were equal to zero. Also we had a constraints on inputs of system, which are shown in equation(3).

$$-1 \leq u(k) \geq 1 \tag{3}$$

The reference r we want to reach by regulation was set up to value *one*.

2 Simulation of the different MPC setups

The initial setup, where parameters of regulator were given like $Q = 10, N = 10$ and $R = 1$ can be seen on Figure 1. Parameters of individual MPC setups with control performance criteria are listed in the Table 1. Control performance of ech regulator is described by three control criteria, which are ISE, ISU and maximal overshoot σ. Integral square error ISE is calculated like this:

$$ISE = \int_0^{t_{sim}} e(t)^2 dt \tag{4}$$

where $e(t)$ is regulation error, which is calculated as difference between reference and output of system. ISU is pretty same as ISE just instead of exponentiation regulation error we exponentiate the input of the system.

$$ISU = \int_0^{t_{sim}} u(t)^2 dt \tag{5}$$

This control performance parameter is really important when our inputs are important for us and we don't want to waste with them.

And the last control performance parameter, which is overshoot is calculated as:

$$\sigma = \frac{y_{max} - y_{\infty}}{y_{\infty} - y_0} \tag{6}$$

where y_{∞} is steady-state value of output, y_{max} represent maximal reached value of system output and y_0 is starting value of process, which is null for our system.

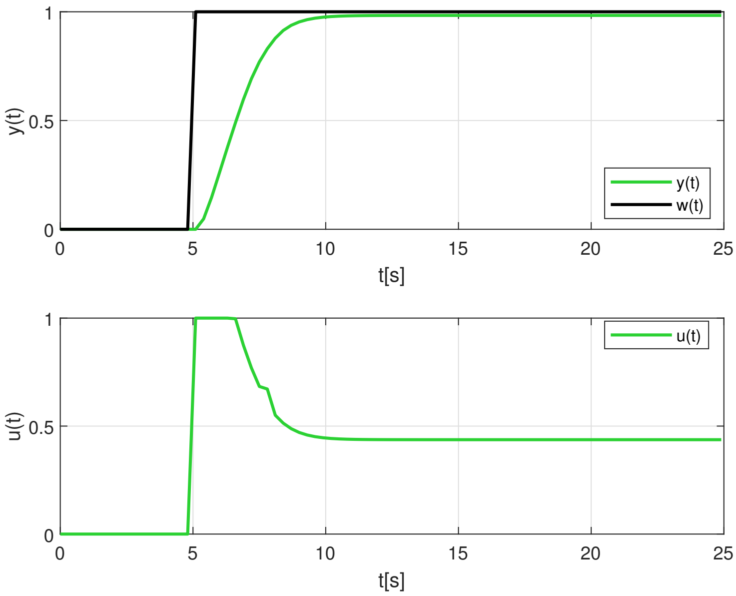

Figure 1: Figure of input and output of system for initial setup

On the Figure 1, we can see output and input of the system for initial setup of the MPC. Output almost reached reference and has a small overshoot. By adjusting the constants of regulator, we got the course that reaches the setpoint r. This simulation can bee seen on Figure 2. On the Figures 3 and 4 we tried to decreased control performance parameters ISU and overshoot σ compared to the initial setup of the controller. In both cases, by decreasing these parameters we increased offset.

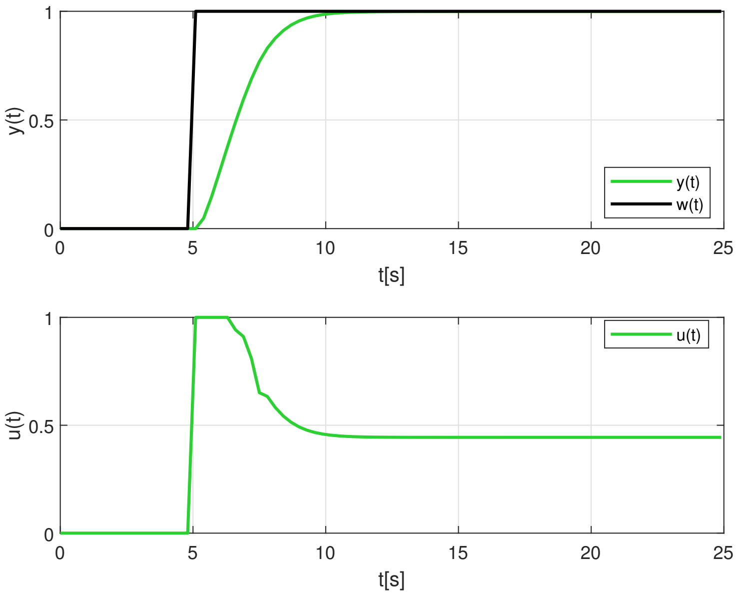

Figure 2: Figure of input and output of system for decreased offset

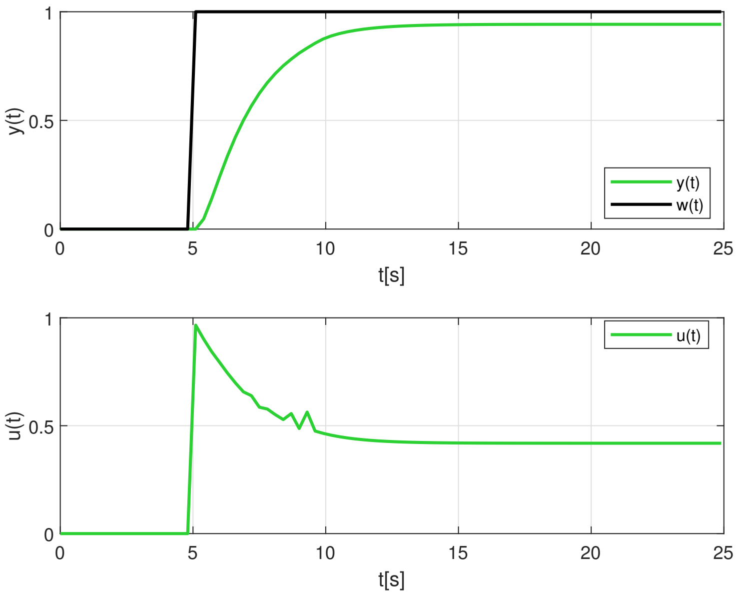

Figure 3: Figure of input and output of system for decreased ISU

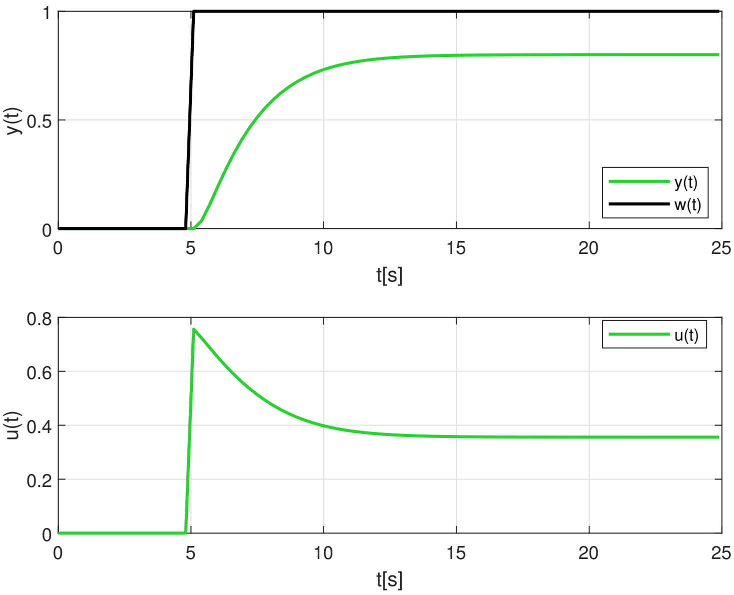

Figure 4: Figure of input and output of system for decreased overshoot

	N	Q	R	ISU	ISE	σ(overshoot)
Initial Setup	10	10	1	5.8027	1.2637	0
Decreased Offset	9	34	2	5.9231	1.2608	0
Decreased ISU	8	46	4	4.9060	1.5541	0
Decreased σ	3	57	3	3.4684	2.4938	0

Table 1: Table of MPC setups

3 Conclusion

The aim of this assignment was to design model predictive controller MPC and by different setups investigate the influence of the regulator parameters Q, R and N. In the first step, we needed to transfer continuous time system to discrete time state space model to obtain matrices, which are necessary to design MPC. After that, we tried multiple setups of the controller to decreased individual control performance parameters. From the table and our simulations we can conclude that by increasing parameter Q the system is more aggressive and the exact opposite is valid for increasing R. By decreasing regulator parameter N increasing the offset a little bit, but mostly increasing maximal overshoot σ and decreasing ISU.